ANSWERS: Buffer solutions

1.

$$K_a = \frac{[F^-][H_3O^+]}{[HF]}$$

$$10^{-3.17} = \frac{[F^-] \times 10^{-4.02}}{0.0500}$$

$$[F^-] = 0.354 \text{ mol L}^{-1}$$

$$n(NaF) = 0.354 \text{ mol L}^{-1} \times 0.150 \text{ L} = 0.0531 \text{ mol}$$

$$m(NaF) = 0.0531 \text{ mol} \times 42.0 \text{ g mol}^{-1} = 2.23 \text{ g}$$

2.

$$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]}$$

$$[H_3O^+] = \frac{K_a[CH_3NH_3^+]}{[CH_3NH_2]}$$

$$[CH_3NH_2] = \frac{30 \times 10^{-3} \times 1}{50 \times 10^{-3}} = 0.600 \text{ mol L}^{-1}$$

$$[CH_3NH_3^+] = \frac{20 \times 10^{-3} \times 1}{50 \times 10^{-3}} = 0.400 \text{ mol L}^{-1}$$

$$[H_3O^+] = 1.52705 \times 10^{-11} \text{ mol L}^{-1}$$

$$pH = 10.8$$

2. cont…Candidates should not be penalised for using ratio of volume and getting correct answer.
When a small amount of acid (H_3O^+) ions are added, they will react with the CH_3NH_2(*aq*) molecules to form $CH_3NH_3^+$(*aq*) ions.

$CH_3NH_2(aq) + H_3O^+(aq) \rightarrow CH_3NH_3^+(aq) + H_2O(\ell)$

The added acid (H_3O^+), is mostly consumed, and the pH of the solution changes very little.

3. a)

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

$[NH_4^+] = [NH_3]\ [H_3O^+] / K_a$

$[NH_4^+] = 0.150 \times 10^{-8.60} / 10^{-9.24}$

$[NH_4^+] = 0.655 \text{ mol L}^{-1}$

$n\ (NH_4^+) = 0.655 \text{ mol L}^{-1} \times 0.250 \text{ L} = 0.164 \text{ mol}$

$m\ (NH_4Cl) = 0.164 \text{ mol} \times 53.5 \text{ g mol}^{-1} = 8.76 \text{ g}$

Note: allow use of $pH = pK_a + \log [NH_3] / [NH_4^+]$

b) A buffer is a solution that undergoes a minimal change of pH when small amounts of acid or base are added.
Added acid will react with NH_3 so that there is almost no change in $[H_3O^+]$:

$$NH_3 + H_3O^+ \rightarrow NH_4^+ + H_2O$$

Added base will react with NH_4^+ so that there is almost no change in[OH–]:

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$

(These equations show that the ratio of NH_3: NH_4^+ changes slightly, but this does not significantly affect the pH.)
Since the pH of the buffer is lower than the p*K*a of NH_4^+, the $[NH_4^+]$ will be higher than the $[NH_3]$. This means the buffer will be more effective against added base.

4. a) C_6H_5COOH, $C_6H_5COO^-$, OH^-, Na^+
(Only one species in each box)

b) A buffer is a solution containing a weak acid and its conjugate base (or a weak base and its conjugate acid). It is able to resist changes in pH.

When 9.80 mL of base has been added, some of the benzoic acid has been converted to the benzoate ion (the conjugate base). There is still unreacted benzoic acid in the reaction vessel, so both acid and conjugate base are present together in reasonable / sufficient amounts. Hence the solution has buffering properties.

When 25 mL of base has been added, the acid molecules have been converted to the conjugate base. The amount of benzoic acid is too low to have buffering properties.

c) Thymol blue or thymol blue and phenolphthalein would be best.
(May state thymol blue is best OR both thymol blue and phenolphthalein would be best depending on justification and pH value chosen)

A suitable indicator is one that has a pK_a and therefore its colour change at the equivalence point of the reaction indicated by the steep / vertical part of the curve. From the graph, the equivalence point is about 8.3. Both thymol blue and phenolphthalein are suitable because their pK_a values are within 1 of the equivalence point.

Methyl orange is unsuitable because it will change colour before the equivalence point is reached / volume indicated will incorrect / give wrong answer.